RICHARD HENRY WHITEHEAD

Professor Richard Henry Whitehead, Dean of the Medical School and Professor of Anatomy at the University of Virginia, died at his home in Charlottesville on the morning of February sixth after a brief illness with pneumonia.

Doctor Whitehead was born in Salisbury, N. C., on July twenty-seventh, 1865. He received his academic training at Wake Forest College where he was graduated with the bachelor of arts degree in 1886. The same autumn he entered the Medical School of the University of Virginia, and completed the regular two years' course then required for the M.D. degree in one year. He was appointed a demonstrator in Anatomy the following session, in which capacity he served until 1889. The winter of 1889–90 was spent in further study in various hospitals in New York. In the fall of 1890 he was called to become Professor of Anatomy and Dean in the Medical School of the University of North Carolina. From 1896 to 1905 he held also the chair of Pathology. It may be truly said that the Medical School of the University of North Carolina is chiefly the product of his inspiration and effort. The summer vacations from 1900 to 1905 were spent in research work in the Pathological Laboratory of the Johns Hopkins University and in the Hull Anatomical Laboratory of Chicago University.

In 1905 Doctor Whitehead was called to the chair of Anatomy and the Deanship of the Medical School of the University of Virginia. During the ensuing eleven years he gave unstintingly of his strength and sound judgment to the organization and maintenance of a Medical School of the first rank at the University of Virginia. In 1909 the University of North Carolina conferred upon him the degree of Doctor of Laws.

Since 1900 Doctor Whitehead had been active in research. The bulk of his work centers about the interstitial cells of Ley-

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dig. His eight papers touching this subject have substantially advanced our knowledge regarding the development, structure and function of these elements. His text-book of the Anatomy of the Brain remains a model of the brief and simple presentation of the fundamentals of a difficult subject. During the past few years various administrative duties of the Dean's office encroached more and more upon his time and strength and necessarily limited his research activity.

Doctor Whitehead was a frequent attendant at the meetings of the American Association of Anatomists. The quiet and unassuming manner of the man, and the clear and concise way in which he presented an occasional contribution made a decided impression upon his colleagues. He was a man who combined in a singular manner the virtues of gentleness and courage; he was a beloved and inspiring teacher; as an anatomist he was animated by the highest scientific ideals, and he displayed a vigor in the prosecution of an investigation and a caution in the formulation of deductions that were an inspiration and a guide both to his students and his colleagues.

In the very prime of his life death summoned the man who has filled a large place in a superbly efficient way; and whom it seems impossible to spare. Anatomical science has lost a loyal devotee, medical education a wise and farsighted counsellor, the Medical School of the University of Virginia a central pillar, and his many friends a perennial source of sympathy and helpfulness.

H. E. JORDAN.

RICHARD HENRY WHITEHEAD

A CHRONOLOGICAL LIST OF PROFESSOR WHITEHEAD'S SCIENTIFIC PUBLICATIONS

1900 A contribution to the study of malignant tumors arising in congenital moles. The Johns Hopkins Hospital Bulletin, No. 114, pp. 221–224.

1901 The anatomy of the brain (a text-book for medical students). F. A. Davis Co., Philadelphia.

1903 The histogenesis of the adrenal in the pig. Am. Jour. Anat., vol. 2, pp. 349–360.

1904 The embryonic development of the interstitial cells of Leydig. Am. Jour. Anat., vol. 3, pp. 167–182.

1905 Studies on the interstitial cells of Leydig, No. 2. Their postembryonic development in the pig. Am. Jour. Anat., vol. 4, pp. 193–197.

A malignant teratoma of the perineum. Jour. Exp. Med., vol. 6, pp. 401–406.

1908 Studies on the interstitial cells of Leydig, No. 3. Histology. Am. Jour. Anat., vol. 7, pp. 213–227.

A peculiar case of cryptorchism, and its bearing upon the problem of the function of the interstitial cells of the testis. Anat. Rec., vol. 2, pp. 177–181.

1909 A note on the absorption of fat. Am. Jour. Physiol., vol. 24, pp. 294–296.

A description of a human thoracophagus, with a consideration of its formal genesis. Anat. Rec., vol. 3, pp. 447–457.

A case of Cyclopia, Anat. Rec., vol. 3, pp. 286-290. (Proc. Am. Assoc. Anats.)

The interstitial cells of the testis of an hermaphrodite horse. Anat. Rec., vol. 3, p. 264.

1911 The early development of the mammalian sternum (with Dr. J. A. Waddell). Am. Jour. Anat., vol. 12, pp. 89–106.

1912 On the chemical nature of certain granules in the interstitial cells of the testis. Am. Jour. Anat., vol. 14, pp. 63–70.

1913 The structure of a testis from a case of human hermaphroditism. Anat. Rec., vol. 7, pp. 83–90.

1914 Vital staining of the interstitial cells of the testis. Anat. Rec., vol. 8, p. 104. (Proc. Am. Assoc. Anats.)

1915 A study of reversal of the circulation in the lower extremity. (With Dr. J. Shelton Horsley of Richmond, Va.) Jour. Am. Med. Assoc., vol. 64, pp. 873–877.

ON THE DEVELOPMENT OF THE PULMONARY CIRCULATION IN THE CHICK

THEODORE L. SQUIER

From the Zoological Laboratory of the University of Michigan

THREE TEXT FIGURES AND TWO PLATES

INTRODUCTION

Although the chick long ago achieved the position of a classic in embryological studies, certain crucial details in the establishment of its pulmonary circulation have been left in the greatest obscurity. The textbooks for many years have been giving accounts, adequate enough, of the origin of the pulmonary artery, but the development of the corresponding vein has for the most part been mentioned only incidentally in connection with hatching (Lillie). Even with respect to the arterial course in the lung proper, particularly its relation to the capillary system, there remains doubt, for the exact time and mode of completion of this portion of the circuit has not been directly determined in the chick, nor for the most part as closely inferred from investigations on other forms as it might have been. It was for these reasons that I began an investigation of this subject at the suggestion and under the direction of Professor Otto C. Glaser.

METHODS AND RESULTS

The first stage of which I made injections was the 96 hour embryo. If the pulmonary circuit is complete at this time it should be possible to inject the vessels from the vitelline artery or vein. Accordingly, while the embryonic heart was still beating, india ink was injected through the vitelline artery by Knower's bulb method (Knower, '08). Care was used, of

course, not to injure the vitelline vessels at any time, and by keeping the embryo covered as much as possible with warm saline solution the heart action was prolonged and better injections secured. The injected chicks were fixed in Bouin's fluid, stained with borax-carmine, and after imbedding in paraffin cross sections were cut 10 μ thick.

A cursory examination of such sections prepared from a 96 hour embryo (the length determined from the number of sections was 9.64 mm.) at once showed that the ink had entered all the smaller vessels, and about the lung rudiments a large number of injected capillary tubules were found. From this it is conclusively shown that a very considerable portion of the pulmonary circuit is complete at this time, but whether the entire course is complete and what its exact relations to the rest of the circulatory system are, could only be determined by means of reconstructions.

Because of the minuteness of the structures under consideration, reconstructions in wax could not be undertaken. Instead, the graphic method was resorted to with entirely satisfactory results. I reflected the sections at 300 diameters magnification and outlined the lungs and the surrounding vessels. Then by projecting each of these separate drawings the final reconstruction reproduced in plate 1 was completed. The drawing represents the left lung rudiment and its surrounding plexus of vessels viewed from the medial surface. The right rudiment corresponds so closely to the left with respect to the number and development of pouches as not to warrant a separate description. Throughout I will designate that side of the lung rudiment which faces the middle line of the embryo as the medial surface and the side directed away from the middle line will be spoken of as the lateral surface.

The left lung rudiment at 96 hours consists of three well marked pouches budding from the dorsal side of the bronchus. The first, or most anterior of these, plate 1, *g*, is the largest. The second and third, *h* and *i*, decrease rapidly in size. Posterior to the last pouch, *i*, a broad swelling dorsal in position denotes the beginning of a fourth pouch.

The rudiment in question extends through 143 sections, that of the right lung through 135 sections (10 μ thick) counting from the bifurcation of the bronchus. Anteriorly the pulmonary artery forms an extensive plexus, *p*, the principle portion of which lies dorsal to the bronchus. One arterial branch, *s*, courses in a ventral direction from the plexus around the median surface of the bronchus and closely approaches a dorsally directed vessel, *r*, itself a tributary of the median cranial vessel, *t*, which joins the left pulmonary vein just before this unites with the corresponding vein on the right. Such an arrangement is certainly very suggestive of a previous anastomosis between artery and vein. From the cranial plexus, *p*, the lung artery, *a*, proceeds along the external surface of the bronchus and is unbranched until the expanded portion of the lung proper is reached. Immediately before reaching the lung the artery is quite small. It continues along the dorso-lateral surface of the lung rudiment in nearly a straight line and gives off two branches the first of which, plate 2, *j*, provides for the most anterior lung pouch, while the second branch, *k*, provides for both the second and third pouches. Distally the artery anastomoses with the vein in the region indicated by *x* in plate 1, and also it gives off two lateral branches shown at *l* and *m* in plate 2 which end blindly.

On the ventro-medial surface of the lung rudiment three main venous lines of drainage (*u*, *v*, *w*, plate 1) are established. The anterior vessel, *u*, is the largest, as would be expected, since it drains the oldest and largest of the bronchial pouches. The other two veins show a decrease in size corresponding approximately to the decrease in size of the vesicles which they drain. The left tributary, *d*, of the pulmonary vein, formed by the union of the three lateral vessels, turns ventro-medially from the bronchus at an abrupt angle to unite with the corresponding venous tributary from the right lung. The common stem thus formed follows a nearly straight course ventralward and empties into the left auricle of the heart as described by Federow in the case of a duck of 4 days, 13 hours: "Die Einmündung der Vene durchbohrt den Vorkammerschiedewandgrund schräg

und öffnet sich an der linken Seite des Septum. Dasselbe ist mit dem Vorkammerboden verschmolzen."

No caudal connection exists between the splanchnic plexus and the vessels of the lungs, and in this stage no trace of such connection is indicated.

In order to verify the essential correctness of the reconstruction, I cut sagittal sections 200 μ thick of a 96 hour injected embryo. The result was very satisfactory indeed, since the sections were thick enough to show the course of the circulatory vessels even more clearly than would actual dissection of the organs concerned. The thickness of the sections precluded the possibility of counting the secondary lung vesicles or pouches. The general course of the vessels is the same as found in the reconstruction. Several features of the cranial arterial plexus are shown here (fig. 1) however, that are omitted in the reconstruction owing to the fact that the latter does not include the most anterior part of the plexus. The artery, *a*, sends a single dorsally directed branch, *e*, to the gut. Near this dorsal branch two ventral branches are given off and the anterior of these, *j*, branches immediately into two stems which eventually anastomose with a plexus that empties into the median cranial branch of the pulmonary vein. Cranially an intricate dorsal plexus, *d*, is given off by the artery and its anastomosing branches extend cephalad possibly as far as the level of the first gill arch (compare with *p*, plate 1). The plexus, *f*, surrounding the lung proper is very similar to that found in the reconstruction. The artery, *a*, follows the dorsal surface of the bronchus (in the figure faintly indicated by a slightly darker area) as described in the preceding embryo, and between the last cephalic branch, *s*, and the level of the lung proper it is unbranched and of uniform diameter. In the section next adjoining that figured a small caudally directed branch arises from the common stem of the pulmonary vein near the union of the right and left main tributaries and anastomoses with the plexus of blood vessels surrounding the gut posterior to the lungs. The same section also shows the median-cranial tributary of the vein and its arterial anastomosis already described in the preceding embryo.

In the 96 hour chick then, the pulmonary circulatory system is complete. The vein stem which empties into the right auricle proceeds dorsally for a short distance and then branches into right and left veins which drain the corresponding lung rudiments.

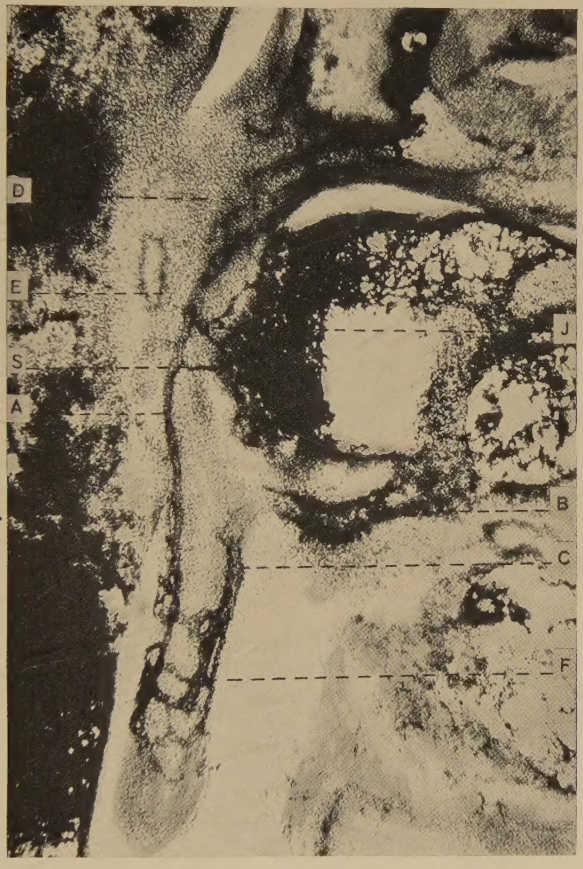


Fig. 1 Photograph of sagittal section 200 μ thick of injected 96 hour chick showing general course of right artery and vein together with plexus surrounding the right lung rudiment; $\times$ 97. *a*, pulmonary artery; *d*, cephalic plexus surrounding gut; *j*, arterial stems that anastomose with the median cranial vein tributary (not shown); *b*, common stem of pulmonary vein; *c*, left pulmonary vein; *f*, plexus surrounding the right lung rudiment. Region of bronchus and lung rudiment is indicated by the dark area in the neighborhood of the plexus, *f*, and the pulmonary artery.

The left vein, near its union with the right, receives a tributary which runs in a cranial direction midway between the lung rudiments and which forms anastomoses with ventrally directed branches from the lung artery. These anastomoses may or may not persist at 96 hours.

Sections 10 μ thick were prepared from a 72 hour injected embryo measuring 6.56 mm. (the length was determined from the number of sections). The lung anlage consists of a right and left primary rudiment. No secondary lateral vesicles are present. The distal ends of the primary bronchi are slightly swollen into pouches. The common stem of the pulmonary vein empties into the left side of the sinus venosus at *b*, figure 2. From this point the vein stem runs dorsalward for a short distance and then receives its right and left tributaries, *c* and *d*, which drain the ventral sides of the right and left lung vesicles respectively, where, as clearly shown by the injections, they form capillary baskets distinguished from those of the 96 hour stage by greater simplicity.

Just before the confluence of right and left veins, a comparatively large vessel empties into the dorsal side of the common pulmonary stem. This last named tributary runs to the ventral side of the gut where it branches and the two veins (*e*, fig. 2), after forming anastomoses with branches from the pulmonary arteries, parallel each other in a caudal direction until the level of the distal ends of the lung rudiments has been reached. Here their identity becomes lost in a general plexus surrounding the gut.

Frontal sections 200 μ thick of this stage were also cut. The lung anlagen are in about the same stage of development as in the 72 hour embryo just described. The right and left primary lung vesicles as shown in figure 3, *l*, are without secondary pouches, and the distal end of each is slightly swollen. The common stem of the pulmonary vein receives the right and left vessels, *d* and *c*, at a point midway between the two primary vesicles, and nearly midway between the proximal and distal ends of the bronchi. In addition to the main vessels draining the right and left lung rudiments, two cephalic branches arise from the common stem. The branch, *g*, which lies to the left,

leaves the stem vein without dividing, while the other, *h*, which is considerably larger, bifurcates almost immediately. All of these vessels run cranialward along a median line between the bronchi. Near the proximal end of the left bronchus a lateral branch, *j*, from the left pulmonary artery crosses the dorsal surface of the bronchus and anastomoses with the cranial end

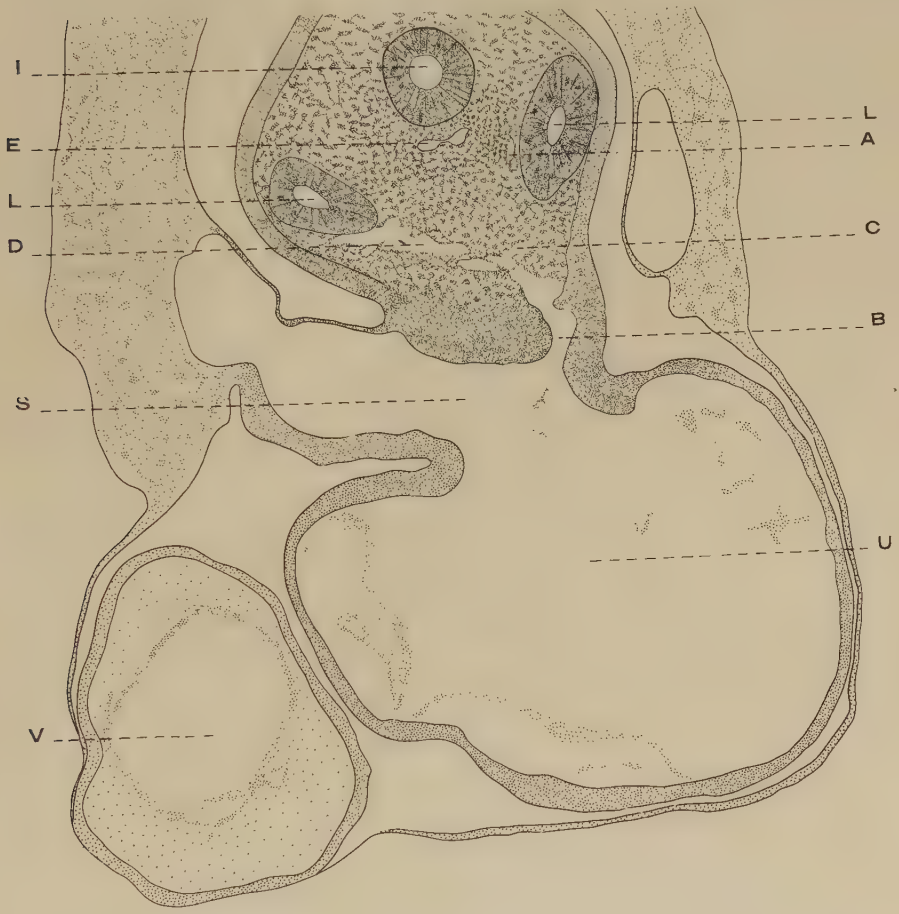
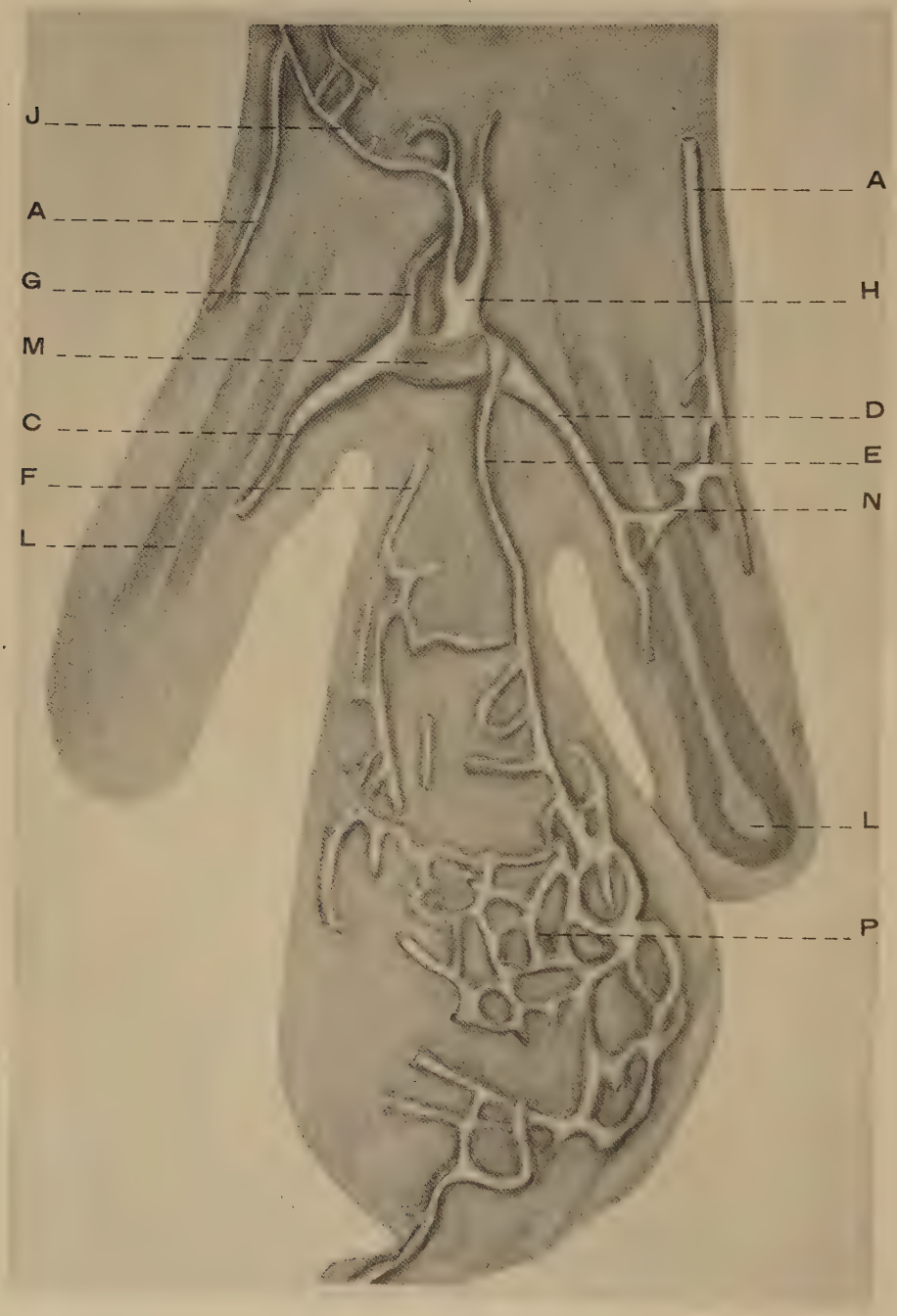


Fig. 2 Cross section of 72 hour chick through region of the sinus venosus and mouth of the pulmonary vein; × 120. *u*, auricle; *v*, ventricle; *b*, common stem of pulmonary vein; *s*, sinus venosus; *c*, *d*, left and right pulmonary veins respectively; *a*, left pulmonary artery; *e*, median vein tributaries; *l*, bronchus; *i*, gut.


J
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of one of the median vein branches. A caudal branch, *e*, is also present, which connects the pulmonary vein with a well developed plexus, *p*, surrounding the posterior portion of the gut.

The vessel, *e*, connecting the gut plexus, *p*, with the right pulmonary vein is very minute and in the preparation was but slightly injected. The exact relations of the corresponding vessel, *f*, on the left have not been determined. Whatever they may be, the evidence from the size of these veins indicates that at 72 hours the blood current flowing between this splanchnic plexus and the pulmonary veins is feeble. The correctness of this supposition is further indicated by the fact that at 96 hours the connections *e* and *f* are either still more weakly indicated or entirely absent. The pulmonary circulation in the 72 hour chick then, is also complete. It differs however from that of the 96 hour stage in two respects: the capillary baskets around the lung rudiments proper are simpler, but the accessory and secondary connections such as those with the splanchnic plexus are more numerous. Furthermore the median cranial tributaries of the pulmonary veins in comparison with the main right and left vein trunks in the 96 hour chick are much larger and as in this latter stage anastomose with the lung arteries.

DISCUSSION

That the pulmonary circuit is complete, though not necessarily in its definitive form in the 72 hour chick is not open to doubt. Granted only that it undergoes gradual correlative metamorphosis during the remainder of the period of incubation, there is left no reason for expecting a circulatory crisis at hatching. The success of my injections shows conclusively that

Fig. 3 Frontal section 200 μ thick of injected 72 hour chick; $\times$ 120. *m*, mouth of common pulmonary vein; *d*, *c*, right and left pulmonary veins; *g*, *h*, median cranial tributaries to common vein; *j*, lateral branch of artery forming anastomosis with median cranial vein; *a*, pulmonary artery; *n*, small portion of plexus of vessels surrounding right lung rudiment; *l*, lung rudiment areas indicated by deeper shading; *e*, caudal tributary to pulmonary vein; *f*, probably a tributary to pulmonary vein with a connection similar to that of *e*; *p*, plexus surrounding gut.

blood must flow through the pulmonary system at a very early stage, although owing to relative resistances in this and the general systemic circulation the amount passing through the lungs is undoubtedly small. With the general enlargement of the pulmonary system, and finally upon collapse of the last aortic arch, a circuit adequate for respiratory purposes is not only at hand, but is automatically put in use.

With respect to the early course of the vein and its anastomoses with the artery, several conditions found correspond in general with those of Federow. The close approach of a branch from the median cranial vein to an arterial branch in the 96 hour chick (plate 1, *r*) has been mentioned above as suggestive of a previous anastomosis which has but recently disappeared. In a duck of 114 hours Federow found a similar condition and says: "Der distale (dem Kopfe nächste) Teil des kranialen Venenastes, der die Anastomosen mit den ventralen Lungenarterien bildet, hat die Verbindung mit dem proximalen Abschnitte des kranialen Astes verloren."

With respect to the anastomosis between the caudal branch from the vein and the plexus surrounding the gut he says:

> Ich möchte hier noch erwähnen, dass der kaudale Venenast bei den Vögeln und Säugetieren (bei den ersteren durch die Gefässe der Speisröhre) eine Zeitlang mit der hinteren Hohlvene in Verbindung steht. Wenn auch diese Verbindung zwischen den Gefässen von ganz verschiedenen Systemen in der topographischen Nähe und in der schwachen Differenzierung der Lunge und des Darmkanals an dem betreffenden Stadium eine gewisse Erklärung findet, so stellt sie sich doch sehr bemerkenswert dar. Etwas Ähnliches beobachtet man bei der Entwickelung der hinteren Hohlvene, nämlich die Verbindung zwischen der V. omphalo-mesenterica und den Vv. cardinales posteriores.

Federow has dealt at length with the origin of the pulmonary vein and concludes that it is produced at a very early stage of embryonic life as a proliferation of endothelium from the dorsal sinus wall which projects into the dorsal mesocardium. Into this proliferation the sinus cavity tunnels, thus producing a short vessel which is the anlage of the vein. This vein, very near its point of origin from the sinus, branches into two vessels

whose ultimate divisions terminate in capillary trees that anastomose with capillary outgrowths from the lung arteries. The vein mouth, which at first empties into the sinus, is finally absorbed into its definitive position as a result of unequal growth of the heart wall.

Brown, on the basis of his investigations on the pulmonary system of the domestic cat, disagrees with Federow's view and holds that the pulmonary veins are differentiated out of an indifferent plexus originally present around the primitive gut and from the beginning connected with the sinus. The vessels of this plexus form numerous anastomoses with the surrounding veins and in addition the plexus "exhibits two well defined connections with the venous portion of the heart, (1) the cephalic or pulmonary, and (2) the caudal or postcaval. These are constant both in occurrence and position." According to Brown's view, therefore, the pulmonary vein is simply a specially developed part of an indifferent plexus present from the beginning in the region from which the lungs grow.

My own observations on the development of the pulmonary circulation do not furnish the basis necessary to decide between these opposed views. Concerning the presence of an extracardiac indifferent plexus, as claimed by Brown there is no doubt. The primitive gut is certainly surrounded by a network of capillaries, and it seems probable that as the lung anlage pushes out from the gut a portion of the surrounding capillary plexus would be carried with it. If this capillary system is derived from angioblast originally continuous with that from which the heart itself is formed, it is easy to see how the pulmonary vein might be nothing more than the survival of a pathway rendered permanent in accordance with the mechanical principle that those vessels in which the blood current is strong become permanent whereas those in which it is weak atrophy and eventually disappear (Mall '10). The numerous early connections between pulmonary arteries and veins which for the most part are lost as early as 96 hours seem to harmonize with this interpretation. In the 72 hour chick, in addition to the pulmonary veins, which persist, there are from one to three

or more branches which run toward the head to form the median cephalic connection with the arteries and caudally one or more vessels connect the vein stem with the plexus of the gut. This latter connection shows signs of atrophy even at 72 hours and in the 96 hour chick from which the reconstruction figured in plate 1 was made it has completely disappeared. The median cranial connections are more persistent and in plate 1 the condition of the vessels indicates that the connection with the left artery has been but recently lost. Accordingly then, the pulmonary vein in the chick could be regarded as complete from the beginning and as representing the sole survivor of numerous primitive vessels that drain the region surrounding the lung anlage.

On the other hand Federow's idea that a median dorsal outgrowth from the sinus connects secondarily with the lung capillaries is not to be set aside lightly. In the first place I have found the outgrowth clearly indicated in embryos earlier than those injected; in the second place its position is identical with that assigned to the earliest indications of the pulmonary vein as given by Brown. It seems quite possible therefore that further investigation might harmonize the two views which so far at least do not necessarily appear mutually exclusive.

In conclusion I wish to acknowledge my indebtedness to Professor Glaser whose suggestions and assistance both in the laboratory work as well as in the preparation of my manuscript have been of the greatest value.

BIBLIOGRAPHY

Bremer, J. L. 1902 On the origin of the pulmonary artery in mammals. Amer. Jour. Anat., vol. 1, no. 2.

Brown, A. J. 1910 The pulmonary vein in the domestic cat. Anat. Rec., vol. 7, no. 9.

Federow, V. 1910 Über die Entwickelung der Lungenvene. Anat. Hefte, 1 Abt. 122 Heft (40 Bd., H. 3).

Flint, J. M. 1907 The development of the lungs. Amer. Jour. Anat., vol. 6, no. 1.

Knower, H. E. 1908 A new and sensitive method of injecting the vessels of small embryos, etc., under the microscope. Anat. Rec., vol. 2. no. 5.

Lillie, F. R. 1908 The development of the chick.

Mall, F. P. 1906 A study of the structural unit of the liver. Amer. Jour. Anat., vol. 5, no. 1.

PLATE 1

EXPLANATION OF FIGURE

Reconstruction of the left lung rudiment and accompanying blood vessels of a 96 hour chick viewed from the medial surface; × 100.

a, left pulmonary artery

d, left pulmonary vein

g, *h*, *i*, first, second and third lung pouches respectively

j, blind ventrally directed arteriole

o, blind distal arterial termination

p, dorsal plexus of artery

r, branch from the median cranial tributary of the pulmonary vein

s, ventrally directed arterial branch which probably previously anastomosed with the dorsally directed vessel, *r*

t, median cranial tributary of the pulmonary vein

u, *v*, *w*, veins draining first, second and third lung pouches respectively

x, distal anastomosis between artery and vein

PLATE 2

EXPLANATION OF FIGURE

Reconstruction of the left lung rudiment and accompanying blood vessels viewed from the lateral surface; × 100.

a, left pulmonary artery
f, left bronchus
g, *h*, *i*, first, second and third lung pouches respectively
j, arterial branch supplying the first lung pouch
k, arterial branch supplying second and third lung pouches
l,*m*, lateral blind arterial branches
n, blind distal termination of vein
o, blind distal termination of artery

THE VITAL STAINING OF MITOCHONDRIA IN TRYPANOSOMA LEWISI WITH JANUS GREEN

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ONE FIGURE

França reported in 1907 that there were granulations in the cytoplasm of certain Trypanosomes (T. costatorum and T. rotatorum) rendered visible by praeagonal staining with neutral red, safranin, methylene blue and pyronin. The last he found to be a true vital stain, since organisms which had been brought into contact with it remained alive and motile for three or four days after they had been stained. He was unable to obtain the same results in trypanosomes parasitic in mammals (T. equiperdum); but Policard ('10) who used a somewhat different technique was able to vitally stain granules in Trypanosoma Brucei, gambiense and equiperdum. He spread a drop of blood into a thin layer between a slide and cover slip, at the edge of which, he placed a drop of concentrated solution of neutral red: the diffusion of the dye into the plasma from the point of contact of the drop with the blood film resulted in a positive stain.

He divided the trypanosomes studied into 3 classes, according to the distribution of granules in the cytoplasm. 1) Those with a few very small granulations. 2) Those with anterior granules and 3) Trypanosomes with anterior and posterior granules. Policard made no attempt to ascertain the chemical composition of the granules which he studied, but he believed that they were not products of the degeneration of the cytoplasm of the organism. He says: "Nous savons seulement que leur reaction n'est pas acide et que ce ne sont pas des produits de dégénérescence, puis qu'on les rencontre chez des trypanosomes au debut

de l'infection. Leur rôle physiologique n'est pas meme encore soupconne."

Michaelis ('99) has recently introduced a vital dye, janus green, which Bensley ('11) and others have shown to have the power of selectively staining mitochondria in living cells; and it was with the hope that this dye could throw some light on the nature and significance of the granules described by Policard and Franca, that it was used in the vital staining of trypanosomes.

Cover glasses were prepared by covering them with a thin film of an alcoholic solution of the dye (95 per cent alcohol, 20.00 cc.; janus green, 00.02 gram), after the technique used by Cesaris Demel ('07) and others to demonstrate the 'sostanza granula-filimentosa' in red blood cells. The film, which is spread on the cover slip with a glass rod, should be even and so thin as to be almost invisible. A drop of blood from an animal (Mus norvegicus albinus) infected artificially with T. Lewisi was allowed to spread between the dyed surface of a cover glass and a clean slide, and was examined at once. The thin crust of dye substance left on the cover slip by the evaporation of the alcoholic vehicle dissolves in the plasma, and forms a solution which at once stains the trypanosomes swimming about in it. Fresh blood was also studied after being mixed on a clean slide with equal parts of 1 to 10,000 solution of janus green in physiologic saline solution. Control preparations were made of infected blood stained with neutral red, pyronin, and di-ethyl-safranin, a dye which has been used by Cowdry ('14) as a vital stain for mitochondria in the human leucocyte. Fixed smear preparations of blood were made and stained after the methods of Bensley, Meves, Altmann and Benda. The smears were exposed to osmic acid vapor for a few minutes before immersion in the fixing fluids in order to prevent any distortion of the granules from drying.

In fresh preparations the trypanosomes move about so rapidly that, in order to study them carefully, it is necessary to add gelatine to the plasma; or to make smear preparations of the blood as soon as the granules are fully stained, which happens in from two to five minutes.

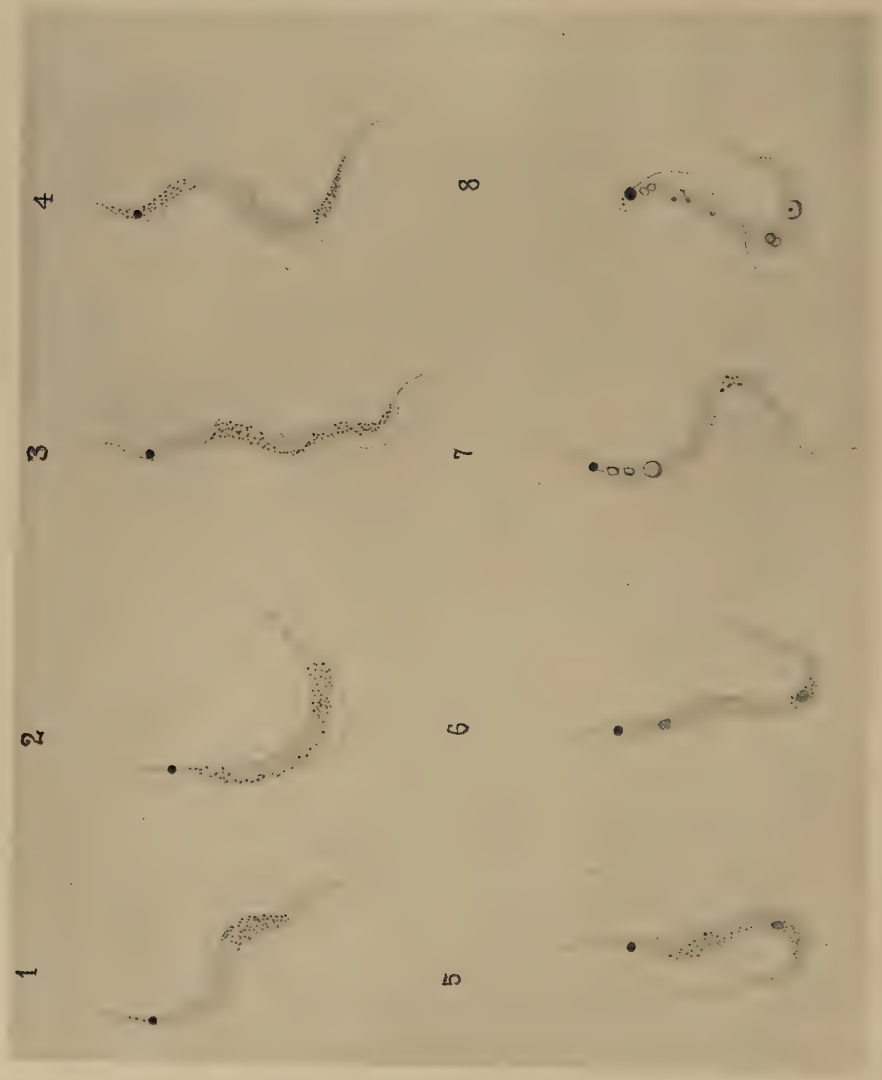
The first structure to stain is the kineto-nucleus which takes up the dye with remarkable avidity even when very dilute solutions are used, and appears as a very bright bluish green rod-like structure. Other stained granules make their appearance in the cytoplasm almost at once. In T. Lewisi the distribution of these granules in the cytoplasm does not adhere strictly to any of the three types suggested by Policard, and trypanosomes of type one, which contains a few very small granules, are extremely rare. They are scattered through the cytoplasm and are most numerous at the anterior end of the organism (figs. 1, 2 and 4). Often they are clumped in a mass just anterior to the nucleus (fig. 1), or there may be a clump at either or both ends of the nucleus (figs. 2, 3, and 5), in which case the granules anterior to the nucleus are most numerous. The tendency to mass formation is very marked. Occasionally organisms are found having a few very fine granules posterior to the kineto-nucleus (figs. 1, 4 and 5).

The granulations vary from the tiniest granules to large swollen masses, which Policard noted as being frequent in trypanosomes from the blood of animals in extremis when involution forms are most frequent (figs. 5, 6, and 8).

Vacuole like bodies sometimes appear in the cytoplasm, are often as large as the nucleus and they are coloured with the vital dye (figs. 7 and 8). One side of the vacuole is always more deeply stained than the other and some vacuoles have a seal ring appearance in optical section (fig. 8 c). Some of these vacuole like bodies contain small granules in their interior which also stain vitally with janus green (fig. 8 b).

The motility of the organisms is apparently in no way affected by the number of these cytoplasmic granules or by their size, except that the swelling of the granules which occurs in dying organisms goes hand in hand with the slowing of movement which characterizes the beginning of their dissolution.

Both the large granules and the vacuole like bodies probably result from swelling, since all transition forms may be found from the fine granules to the fully distended vacuole. They are probably an index of a degenerative change of some sort, because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they are more numerous in trypanosomes which are losing their motility; and often dead swollen organisms are seen in which the vacuoles entirely fill the cytoplasm. Policard noted vacuole like bodies which he differentiated from food vacuoles, etc., by their brick red staining with neutral red. The death of the trypanosomes is followed by the gradual fading of the stain. The nucleus remains uncoloured throughout. In these preparations, as in the fixed smears, the mitochondria in the white blood cells may be seen stained in the same way as the granules in the cytoplasm of the trypanosomes, and in preparations stained with janus green the leucocytic nuclei react as do those of the trypanosomes, remaining uncoloured by the dye for a long time after the mitochondria have taken their characteristic blue green tint.

It is impossible to say definitely that the granules which França and others have seen after supervital staining with neutral red are identical with those which are stained by solution of janus green. The mitochondria of healthy cells do not react in neutral red. Injury to the cell, however, in presence of a basic dye is at once followed by intense coloration of the mitochondria. The trypanosomes swimming about in these dye solutions are cells slowly undergoing toxic death, and are in a condition in which one expects to find mitochondrial staining. It is, therefore, probable that a part at least of França's granules are of mitochondrial nature, and therefore, are identical with the granules which stain selectively with janus green. In organisms treated with di-ethyl-safranin the granules are stained but the staining is neither so sharp nor so constant as when the janus green is used.

In permanent preparations fixed and stained by the methods of Benda, Bensley, Meves and Altmann the same granulations give characteristic mitochondrial staining reactions. The kinetonucleus in particular, stains very brilliantly with the mitochondrial dyes and is sharply contrasted with the surrounding cytoplasm. These granulations show also the solubility in acetic acid which characterizes mitochondria in other situations. After fixation in a solution of osmic acid containing five drops of acetic acid (glacial) to 20 cc. of the solution it is not possible to find

definite isolated granules. Instead a diffuse staining is seen in the region where they normally occur, and if the percentage of acetic acid in the fixing fluid is increased above this amount even the diffuse staining is not found.

These granules show the characteristic reactions of mitochondria toward fixing and staining fluids, and their reaction to vital stains is likewise typical. They exhibit the same sensitiveness to increased acetic acid content of fluids used to fix them, and finally they may be stained in the same way as mitochondria and may be observed side by side with mitochondria in cells known to contain them (blood leucotytes). The conclusion is therefore justified that they are mitochondria.

Extremely interesting in this connection is the reaction of the kineto-nucleus toward mitochondrial stains, both in fixed and vitally stained preparations, indicating as it does a certain similarity between it and the mitochondria of the organism. Whether or no there may be a functional similarity as well, is a question, the answer to which offers the opportunity for a most fascinating study. A close relation of mitochondria to the motor portion of the cell has been asserted, and Benda ('13) has attributed to these granules a function in relation to cytoplasmic contractility because 1) of their microchemical resemblance to the dark bands of striated muscle, 2) their disposition about the axial filament of the spermatozoid and their arrangement and abundance about the roots of the cilia in ciliated cells, expecially those of the amphibian kidney. His view, however, has been opposed by Regaud ('08) who finds that the mitochondria in the ciliated cells of the urinary tubule of cold blooded vertebrates are relatively few in number and have apparently no constant orderly arrangement; and by Fauré-Frémiet ('09) who finds that in Vorticella the mitochondria which are grouped about the axial filament have no relation to its contraction. The mobility of T. Lewisi is certainly unaffected by the amount of mitochondrial substance in the cell cytoplasm. At any rate a further study of the mitochondria of the Trypanosomata during cell division, especially in the so called abrephaloplastic forms, is necessary before one can include the mitochondria with the kineto-nucleus of these organisms in speaking of differentiated kinoplasm.

BIBLIOGRAPHY

Benda 1913 Cited by Regaud C. R. des de le Soc. Biol.

Bensley, R. R. 1911 Studies on the pancreas of the guinea pig. Amer. Jour. Anat., vol. 12, pp. 297–388.

Cesaris, Demel A. 1907 Studien über die roten Blutkörperchen mit den Methoden der Färbung in frischen Zustande. Folia Haematologica Bd. 18, Supp. 41, S. 1 to 32.

Cowdry, E. V. 1914 The vital staining of mitochondria in human blood cells. Internat. Monatsschr. Bd. 31, pp. 267–284.

Fauré-Frémiet 1909 Discussion of the work of Regaud and Mawas "Sur le structure du protoplasma, etc. "Communications Association des Anatomistes. Nancy.

Franca, C. 1907 Coloration vital des Trypanosomes. Bull. de la soc. Portugais des Sciences Nat., pp. 8–11.

Michaelis, L. 1899 Die vitale Färbung, eine Darstellungs methode der Zellgranula. Arch. f. mikr. Anat., Bd. 55, S. 558–575.

Policard, A. 1910 Sur la coloration vitale des Trypanosomes. C. R. de la Soc. Biol. 19 Mars. N. 11, pp. 505–507.
Sur les mitochondries des cellules ciliees du tube urinaire.

Regaud Cl. 1908 C. R. des Seances de la Soc. Biol., 25 Juillet, T. 65, p. 206.

A SUGGESTION AS TO THE PROCESS OF OVULATION AND OVARIAN CYST FORMATION[1]

A PRELIMINARY REPORT

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It is generally conceded, that pressure atrophy of the ovarian stroma is the chief means by which the extrusion of the ovum becomes possible. During the growth and maturation of the ovum, the cells of the Graafian follicle, after increasing greatly in number, begin to disintegrate and liquefy. From then onward, due it is thought to the different chemical composition of the liquor, thus forming in the follicle, or of the general content of the follicle, an endosmosis seems to be induced by which the liquor folliculi increases to a far greater amount than is thought possible to result from the liquefaction of the follicular cells. The follicle so distends that, following the direction of least resistance, one side of it approaches the free surface of the ovary, producing a bulging in this surface, dispersing the ovarian stroma, thinning its tunica albuginea and the overlying epithelium, and results in a compression of the blood capillaries intervening between it and the surface of the ovary. Clark has shown that the capillaries in the summit of the bulging are practically obliterated by the pressure. It is supposed that nourishment thus cut off from the ovarian stroma under compression, the stroma atrophies till its resistance is less than the pressure exerted by the distending follicle and the content of the follicle bursts into the body cavity. The liquefying of the follicular cells having continued till the ovum is free within the follicle, the ovum is extruded into the body cavity with the discharge of the liquor folliculi.

Proc. Amer. Asso. Anatomists, New Haven, December 30, 1915.

The question was suggested by Dr. Irving Hardesty as to whether the liquor folliculi does not exert some special digestive action upon the resisting tissues thus aiding in the process by which the ovum is extruded. The idea carried with it the action of the liquor folliculi in the phenomena of menstruation.

Accordingly, a series of experiments were made, the result of which may be of interest. The work was undertaken with the view to determine:

1) Whether the liquor folliculi has a digestive action and if so does it possess a specific enzyme that can be demonstrated by dialysis or other tests?

2) If it possesses such action, under what conditions is it altered? Is it decreased in pathological conditions?

3) If possessed, will a quantitative estimate of its strength indicate the amount of it present.

A review of the literature has failed to suggest any special chemical action of the liquor folliculi, and nothing of its chemical composition except that it is a para-albumen.

MATERIALS AND METHODS

Obviously only small quantities of the liquor can be obtained at best. Human material is not available sufficiently fresh and in sufficient abundance. Therefore, it was necessary to obtain it from ovaries of animals available in large numbers and freshly killed.

Ovaries of the sexually mature hog (sus Scrofa) were used, as these could be very readily obtained in the slaughter houses of New Orleans. All histological observations indicate, that the process of the production of the liquor folliculi in the Graafian follicle and the process of extrusion of the ovum are the same in the human as in the hog; and it is logical to assume that the liquor plays the same rôle as in the human ovulation and that any results indicating its physiological action in the hog must be similar to the human. In the experiments, amniotic fluid and fluid from ovarian cysts of the hog were used for comparison with liquor folliculi, and also fluid from human ovarian cysts.

The Graafian follicles may be readily distinguished in the surface of the ovary from the corpora lutea and ovarian cysts by their reddish color and manifest turgidity. The corpora lutea are yellowish spherical protrusions of firm consistency, and the cysts are translucent and usually larger. The liquor folliculi was obtained by inserting into the large follicles a fine needle of small, dry, thoroughly sterilized, all glass syringe. All material was collected at the slaughter house under rigid aseptic precautions from ovaries of freshly killed animals. The hog being one of the animals, which give birth to litters of young, ovaries may be obtained containing a number of mature follicles. Obviously but a few drops of the liquor could be obtained from a single follicle. All ovaries were taken warm just as the viscera were removed. It was noticed that if allowed to cool only a very small quantity or none could be obtained, due probably to coagulation.

The experimental technique used in this work is based on the principles of Abderhalden's dialyzation reaction with its modification by Grützner. It may be briefly summarized: 1) in preparation of material to be tested; 2) process of obtaining the liquor folliculi; 3) diffusion tubes; 4) the test; 5) dialyzation; and 6) the controls.

In preparation of the material for the digestive experiments, blood was obtained, defibrinated, and the fibrin thoroughly washed in cold water until all blood was removed from it. The pieces of fibrin containing the faintest tinge of pink were discarded to eliminate whatever reaction any blood or plasma themselves might give. Pieces of fibrous connective tissue, muscle, and ovary were also used. These were boiled in distilled water for five minutes and the filtrate tested for substances reacting with ninhydrin and with the biuret reaction. This was repeated until the filtrate failed to give a reaction with one cubic centimeter of ninhydrin on boiling one minute. The fibrin in Grützner's test was prepared according to the method devised by him, which must be omitted as time and space will not permit.

Schlercher and Schull, No. 579 dialyzing tubes were used. These were first carefully tested with albumen to insure imper-

meability to it. They were then boiled for five minutes just before each test.

In the test, small quantities of liquor folliculi were introduced into the diffusion tubes together with a small piece of muscle, fibrous connective tissue, and ovarian tissue, prepared as above; separate tubes being used for each. Care was taken that all tissues were below the surface of the liquor folliculi to prevent any possible error from decomposition of pieces. The diffusion tubes were next placed in larger tubes of sterile distilled water. A layer of xylene was placed upon the fluids within and without the dialyzer to prevent the growth of bacteria and to prevent evaporation.

Controls were made with exactly the same technique using amniotic fluid, normal saline, and cystic fluid, instead of liquor folliculi. Cultures were made from the liquor folliculi and cystic fluid used; to rule out any possibility of digested protein due to bacterial action.

The period of incubation was twenty-four hours, as some difficulty was experienced in tests of shorter periods of incubation due to weak reactions. Abderhalden also employed and later advised this modification as to time. The temperature of incubation was 38°C. The filtrate or the fluid in the tube surrounding the dialyzers were tested with ninhydrin and the biuret test.

The results obtained may be tabulated as follows:

1. Abderhalden's dialyzation reaction

	OVARIAN TISSUE	MUSCLE	LIGAMENT	FIBRIN
Liquor folliculi	+++	++	++	+++
Cystic fluid (small cysts)	++	+	+	+
Amniotic fluid	−	−	−	−
Normal saline	−	−	−	−

2. Grützner's fibrin test

Liquor folliculi	+++			
Amniotic fluid	− − −			
Normal saline	− − −			

Sixteen tests were made with the dialyzation method which was repeated three times, making a total of forty-eight tests to which may be added the tests of Grützner's Method.

As indicated in the table, the liquor folliculi gave a positive reaction with fibrin, fibrous connective tissue (lig. nuchae), muscle and especially a strong reaction with ovarian tissue. Slight positive reactions were obtained with cystic fluid from small cysts, and negative results with larger ones. The controls of amniotic fluid and normal saline were found to be uniformly negative with the exception of slight reaction with cystic fluid, (from small cysts) which to my mind is the strongest point in favor of proper technique.

Before drawing any conclusions from the above it might be well to briefly summarize the theories of ovulation.

By ovulation is meant the discharge of a mature ovum from its Graafian follicle. The study of the process involves a consideration of the development of the follicle and its rupture.

In ovulation the earlier stages have received more attention than the late stages, though it is the latter in reality that must explain the rupture of the Graafian follicle. It is admitted by all that the most mature follicle, very probably aided by the condition of premenstrual congestion, rapidly swells to the size of a large pea, due to the accumulation of the liquor folliculi, and produces a hemispherical protrusion of the surface of the ovary.

In considering the forces involved in the formation and increased production of liquor folliculi, the changes occurring in the circulation must be considered.

If the great increase of the liquor folliculi were considered the result of a mere transudation into the follicle, it must be realized that the ordinary blood pressure in the capillaries cannot be the only important factor. It is obvious that the pressure within the enlarged follicle is greater than the blood pressure within the capillaries since the capillaries are compressed by the follicle and even constricted in the summit of its protrusion of the surface of the ovary. The question arises whether this increase of tension of the tissues may increase or decrease the

flow of blood through the tissues and thereby possibly increase or decrease transudation. Compression of veins would result in congestion of the veins behind the region of compression with increased transudation; compression of an area of capillaries must result in congestion of the contributing arterioles and capillaries not affected by the pressure with increased transudation. It is reasonable to assume, however, that an equilibrium would soon be established in which the blood pressure in the veins concerned on the one hand, or the arteries on the other would be no greater than the common blood pressure. The result would be a decreased in the blood supply, in the immediate vicinity of the follicle, beginning in the earlier stages of accumulation of the liquor folliculi. However, the approach of ovulation, or the later stages of the enlargement of the follicle, is accompanied by a marked congestion of the general ovarian and uterine vascular system, and this congestion must result in a greater transudation from the vessels into the tissue spaces. Therefore, it is very probable that the distension of the follicle by the accumulation of its liquor folliculi must be due to causes other than increased blood pressure and resultant transudation from the vessels into the follicle.

It is suggested then that the liquor folliculi must accumulate by a process similar to that of secretion, that the chemical nature of the cells of the Graafian follicle or the product of their liquefaction, or both, may induce an endosmosis into the antrum of the follicle, producing its distension to the pressure greater than that of the tissue about it or of the blood in the ovarian vessels. It is quite conceivable that the chemical composition of the liquor folliculi may vary at different periods, in the process under the agency of the increased number and liquefaction of the follicular cells, as well as the amount of the liquor. Also the layer of cells in the stratum granulosum may act as a diffusion membrane whose control of osmosis may vary at different periods, increasing the endosmotic current in the later stages of enlargement. The congestion of the ovarian vessels is probably induced by the pressure irritation of the enlarging follicle. The chemical character of the follicle may induce it.

This congestion results in a greater transudation from the vessels into the tissues, and the increased fluid in the tissue spaces; but this means a greater amount of fluid for the forces within the follicle to act upon, resulting in the greater enlargement of the follicle and this again irritating to a greater congestion, and so on till the follicle may burst and the cause removed. It would be logical to expect that, during the period of congestion, characteristic of the premenstrual period, a more vigorous elaboration of the products of the cells of the follicle (ferments or enzymes) would be made possible by the increased transudation or nutrition in the tissue spaces.

It is, of course possible, that other forces may contribute to the process of ovulation. We have no evidence that the nervous system has any direct influence. The sympathetic is of course, concerned in the altering of a caliber of the ovarian vessels (vaso-dilators), but this is no doubt a reflex, the impulses, which are aroused by the condition of the ovary itself, affecting the terminations of the nerve fibers in it.

From the comparative results with amniotic fluid, cystic fluid, and normal saline, it is suggested that the digestive action of the liquor folliculi is no mere matter of chance, but is a definite factor depending in some way at present unknown upon the particular nature of the liquor. It is a matter of common knowledge that different enzymes are specific in their action, that is to say, each enzyme acts only on one class of material and acts on it in a determined manner, producing certain specific substances as a result of that action, and that extra-cellular as well as intra-cellular enzymes act only when completely freed from the cell body. As to the enzymic action of the liquor folliculi, the general law which applies elsewhere, may be applied here. The rate at which digestion goes on varies with temperature, with the reaction, the concentration of the digesting substance, and the condition of the material digested. The forces involved may be considered accelerated or aided by the increased temperature in the region of the ovary during the congested stage, more probably accelerated as enzymic action is greater at a temperature slightly above body temperature. The chemical

reaction of the liquor folliculi was found to be alkaline to litmus and phenolsulphopthalein. Practically all the digestive agents of the body act best in the presence of an alkaline reaction. In the experiments here, the liquor folliculi was used in its normal concentration and, as noted above, at a temperature 38°C. or slightly above the normal body temperature.

THEORIES OF RUPTURE OF FOLLICLE

The purely mechanical theory of Hensen who ascribed the rupture of the Graafian follicle to be due solely to pressure atrophy, due to the increase of the liquor folliculi can no longer be held tenable, as Naegel has shown that an increased pressure causes a thickening of the tunica interna of the theca folliculi. The thickening of the theca folliculi about the enlarging follicle is very evident in all sections, and may be explained as due to two causes:

1. The mere fact that the liquor folliculi does increase in amount, and the follicle increases greatly in size must result in a packing off, or compression of the ovarian stroma about the follicle and thus in a gradual increase in the thickness of its theca.

2. It is well known that in certain other conditions in the body any gradually increasing pressure leads to a proliferative fibrosis, and thus the thickening of the elements of the theca interna (an increase in size and in number of the connective tissue corpuscles with a subsequent increase in the fibrous tissue of the theca interna) and, therefore, may be in part but an expression of one of our simple laws of physiology, namely, that all irritation causes proliferation.

According to the earlier views of de Graaf, von Baer, His, and Waldeyer, that the ovum may be extruded through rupture of the Graafian follicle resulting from the formation of a local area of necrosis or macula pellicuda due to a distinctive preformed non vascular area has been shown to be incorrect by the excellent monograph of Clark dealing with the blood supply of the ovary and its changes during ovulation.

In the words of Dr. Clark: "There is undoubtedly a deeper lying cause than the mere growth and pushing forward of the

follicle until, by erosion of the tunica albuginea of the ovary it empties itself." In his excellent monograph, Dr. Clark summarizes his views of the final epoch in the evolution of the follicle to be due to the arrangement of the vessels and the phenomena of congestion of the internal genital organs. He states, "A follicle may reach maturity through the influence of the normal circulation, but it requires the increase of arterial pressure due to the menstrual wave to induce rupture and extrusion of the ovum."

It is evident that we must go still farther in elucidating the problem of the rupture of the Graafian follicle and determine, if possible, the correct basis on which to build the argument relating to the causative factors for its rupture.

In interpreting the menstrual wave, it has been assumed by many to be due to the congestion of the internal genital organs. From this point of view then, it would seem that any congestion brought about would induce rupture of the follicle. As a matter of fact the stage of preparation, premenstrual congestion begins for some days before ovulation or actual bursting of the follicle (stage of destruction) and capillary pressure gives us an inadequate explanation.

It is suggested that it may be the period at which time the liquor folliculi reaches its maximum amount and the enzyme is liberated in the liquor.

SUMMARY

The rupture of the Graafian follicle is due in part to the digestion of the theca folliculi by a proteolytic ferment or enzyme in the liquor folliculi.

The author wishes to acknowledge his indebtedness to Prof. Irving Hardesty for his constant interest in the progress of this work, and for many helpful criticisms. To Drs. C. W. Duval and H. N. Kingsford for material made available, and to Dr. F. P. Lord for assistance in the preparation.

BIBLIOGRAPHY

AIME, P. 1907 Recherches sur les cellules interstitielles de l'ovaire chez quelques mammiferes. These. Nancy.

ALLEN, B. M. 1904 The embryonic development of the ovary and testis of the Mammalia, Am. Jour. Anat., vol. 3, pp. 89–146.

ANCEL, P., AND BOUIN, P. 1909 Sur les homologies et la signification des glandes à sécrétion interne de l'ovaire. Compt. Rend. Soc. Biol., November 13, T. 61, pp. 497–98.

ARNOLD, L. 1912 Adult human ovaries with follicles containing several oocytes. Anat. Rec., Phil., vol. 6, pp. 413–422.

BENTHIN, W. 1911 Über Follikelatresie in Säugetierovarien. Arch. f. Gynaekol., Bd. 94, pp. 599–636.

BIEDL, A. 1910 Innere Sekretion: ihre physiologischen Grundlagen und ihre Bedeutung fur die Pathologie. Urban and Schwarzenberg.

BOUIN, P. 1902 Les deux glandes à sécrétion interne de l'ovaire: le glande interstitielle et le corps jaune. Rev. Med. de L'Est., Nancy, July 15.

BOUIN, P., AND ANCEL, P. 1909 Sur les homologies et la signification des glandes à sécrétion interne de l'ovaire. Compt. Rend. Soc. Biol., T. 65, vol. 61, pp. 464–466.

CENI, C. 1912 Il cerebello e la funzione ovarica. Riv. sper. di frem., Reggio-Emilia 38, pp. 219–290.

CHAMPY, C., AND GLEY, E. 1911 Action des extraits d' ovaires sur la pression artérielle. Compt. rend. Soc. de biol. Paris, 71, pp. 409–413.

CLARK, J. G. 1901 The origin, development and degeneration of the blood vessels of the human ovary. Johns Hopkins Hosp., vol. 9, pp. 593–676.

COHN, F. 1912 Die klinische Bedeutung der Follikelsprungstellen in Ovarium. Deutsche. med. Wchnschr., Leipz. u. Berl., 38, pp. 780.

CUSHING, HARVEY. 1912 The pituitary body and its disorders, Clinical states, etc., J. B. Lippincott Company, Philadelphia.

COHNHEIM, O. 1912 Enzymes, T. John Weyler and Sons, New York.

FELLNER, O. 1909 Zur Histologie des Ovariums in des Schwangerschaft. Arch. f. mikr. Anat., Bd. 73, pp. 288–305.

FRANK, R. F. 1911 The function of the ovary. Tr. Amer. Gynec. Soc., vol. 35, pp. 269–302.

GANFINI, C. 1907 Sul probabile significato fisiologico dell'atresia follicolare nell'ovain di alcuni mammiferi. Arch. Ital. di. Anat. e di embriol., T. 6, pp. 346–357.

HARZ, W. 1883 Beiträge zur Histologie des Ovariums der Säugethiere. Arch. f. mikr. Anat., Bd. 22, pp. 374–407.

HIS, W. 1865 Beobachtungen uber den Bau des Saugetirereierstocks. Arch. f. mikr. Anat., Bd. 1, pp. 151–202.

HOELZI, H. 1893 Über die Metamorphosen der Graafischen Follikel. Arch. f. pathol. Anat., Bd. 134, pp. 438–473.

ISCOVESCO, H. 1912 The lipoids of the ovary. Univ. m. Rec. Lond. pp. 395–402.

KELLER, R. 1912 Blutgerinnungszeit und Ovarialfunktion. Arch. f. Gynec. Berl. 97, pp. 540–582.

KINGSBURY, B. F. 1913 The morphogenesis of the mammalian ovary (Felis domestica), Am. Jour. Anat., vol. 15, pp. 345–379.

KINGSBURY, B. F. 1914 The interstitial cells of the mammalian ovary: Felis domestica. Am. Jour. Anat., vol. 16, pp. 59–91.

LANE-CLAYPON, JANET E. 1905 On the postnatal formation of primordial ova. Proc. Physiol. Soc. Journ. Physiol., vol. 32, pp. xli–xlii, March 18.

LOB, W., AND GUTMAN, S. 1912 Zur Kenntnis der Enzyme der Ovarien. Biochem. Ztschr. Berl., xli, 445–460.

LOISEL, G. 1904–1905 Les phénomenès de sécrétion dans les glandes génitales. Revue. générale et faits nouveaux. Journ. de l'Anat. et de la Physiol., T. 40, pp. 536, 562, and T. 41, pp. 58–93.

MACLEOD, J. 1880 Contributions à l'étude de la structure de L'ovaire des mammifères. Arch. de Biol., T. 1.

PFLÜGER, W. 1863 Über die Eierstöcke der Säuger und des Menschen. Leipzig.

PROCA, G. 1912 Sur une action particulière de l'ovalbumine. Compt. rend. Soc. biol., Par. T. 72, p. 843.

REGAUD, C., AND LACASSAGNE, A. 1913 Sur les processus de la degenerescence des follicules dans les ovaires röntgenisés de la lapine. Compt. rend. Soc. de biol. Paris, T. 74, pp. 869–871.

SCHULIN, K. 1881 Zur Morphologie des Ovariums. Arch. f. mikr. Anat., Bd. 19, pp. 442–512.

SEITZ, L. 1906 Die Follikelatresie während der Schwangerschaft, insbesondere die Hypertrophie und Hyperplasia der Thecainterna-Zellen und ihre Beziehungen zur Corpus luteumbildung. Arch. f. Gynaek., Bd. 77, pp. 203–356.

VAN DER STRICHT, O. 1901 L'atrésia ovulaire et L'atresia folliculaire du follicule de de Graaf, dans l'ovaire du chauve-souris. Verh. d. Anat. Gesell. zu Bonn., pp. 108.

VINCENT, SWALE 1912 Internal secretion and the Ductless glands. Lond.

WALDEYER, W. 1870 Eierstöck und Ei. Leipzig.

YOUNG, J. S. 1911 The life history of the ovary, Jour. Obsrt. and Gynec. Brit. Emp., Lond., vol. 20, pp. 285–290.

A PORCUPINE SKULL WITH A PAIR OF SUPERNUMERARY WELL DEVELOPED INCISORS IN THE UPPER JAW

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ONE FIGURE

The specimen here recorded and illustrated is unique so far as my observations on rodents extend and I have been unable to find mention of a similar case in the literature on mammals. The anomaly occurs in a young (deciduous premolars and first molars only teeth in place aside from the incisors) male Old World porcupine, Acanthion longicaudum, number 153973, United States National Museum, collected along the Kendawangan River, southwestern Borneo, July 10, 1908, by Dr. W. L. Abbott. This specimen was briefly referred to by me in a faunal paper in 1911.[1] The condition evidently being rare seems worthy of a special note.

The order Rodentia (Gidley[2] has recently shown that the Lagomorphs constitute an order apart from the rodents) is principally characterized among other things by the possession of a single pair of heavy cutting teeth in both upper and lower jaws. It is only in those rodents possessing more than three cheek teeth, in general the so-called Sciuromorphs and Hystricomorphs, that deciduous teeth occur. The one, or sometimes two, premolars usually found in these groups are preceded by milk molars. The first cheek tooth in the specimen here illustrated is a milk molar and was destined to be succeeded by a permanent premolar.

The incisors of rodents, usually considered to be the second

[1] Proc. U. S. Nat. Mus., vol. 40, p. 114, April 25, 1911.

[2] Science, n. s. vol. 36, pp. 285–286, August 30, 1912.

pair of incisors of the generalized mammalian dentition,[3] are to be regarded as members of the permanent dentition rather than permanently retained milk incisors. In mammals when only one set of teeth is functional, it is probably the permanent set as is exemplified in the early shedding of the milk teeth in seals and in bats. If the small additional incisor here illustrated is correctly interpreted, it is further evidence that the cutting teeth of rodents are members of the permanent set of teeth. A consideration of the use of the rodent incisor makes it at once apparent that a rodent must possess permanently functioning incisors as it could ill afford to dispense with such necessary teeth during the period of casting off the milk incisors and the incoming of the permanent ones.

In the porcupine skull under consideration a pair of well developed supernumerary upper incisors is present. The incisors in the lower jaws are normal in every respect. These extra teeth are fairly large. Their shape, size, and relation to the upper incisors are illustrated, natural size, right and left sides, in figure 1 and need no detailed description. The entire incisor socket has been exposed on the right side of the skull and it is there seen that the supernumerary tooth extended posteriorly more than half the length of the normal tooth. During the process of cleaning or handling the skull, a few millimeters of the small right incisor were broken off at the free end. The root of the tooth was situated further back than is shown in the illustration; that is the small incisor on the right side should be placed further back in the socket, and the apparent free edge of the tooth on the right side is not what was its cutting edge. The free distal edge of the small left incisor is worn by contact with the opposing under incisor. The free edge of small now broken off right incisor was without doubt similarly worn. Although showing evidences of wear these teeth could have been of no service to the animal. The left incisor is worn in the reverse direction as compared with the normal rodent incisor, that is, the anterior surface of the tooth is worn away more than the

[3] Weber, Die Säugetiere, p. 480, 1904.

posterior, well shown in the lower view, figure 1. This condition of wear was evidently brought about by the protection afforded the posterior surface as it lay in contact with the hard anterior surface of the normal tooth. The supernumerary inci-

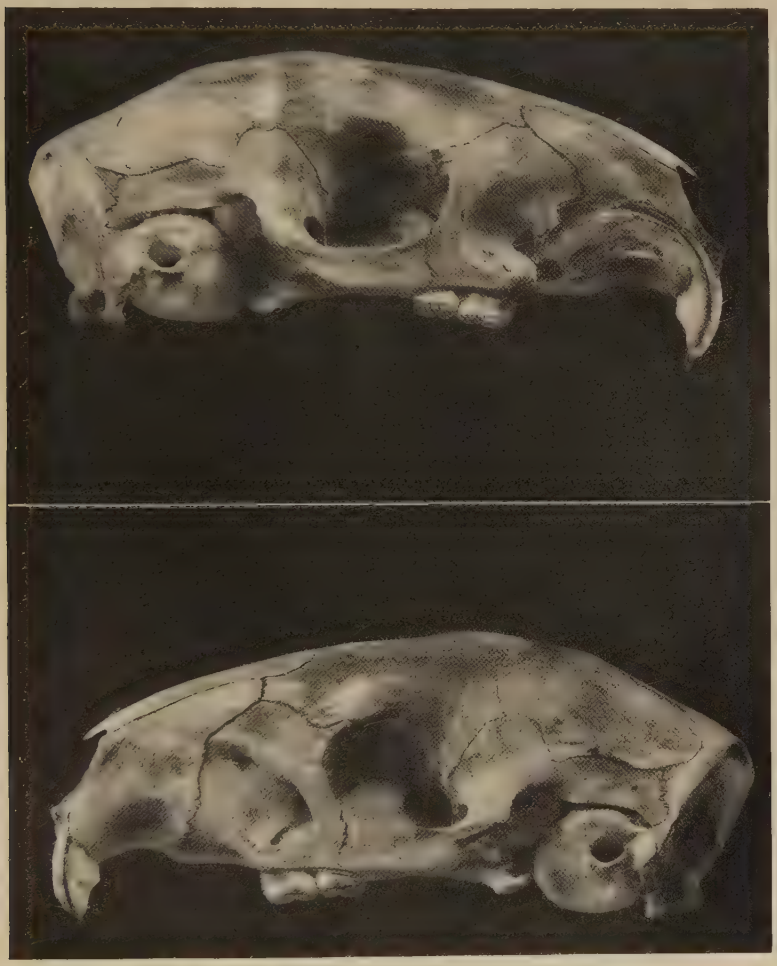


Fig. 1 Natural size view of skull of Old World porcupine, Acanthion longicaudum, number 153973, United States National Museum, from southwestern Borneo, collected by Dr. W. L. Abbott. It shows a small pair of extra incisors lying in front of the normal incisors.

sors seem to have an ill-defined layer of enamel covering them all around. In the center of the free extremities of these incisors is seen the remains of the dental canal just as it is also seen in the free extremities of the normal incisors. The posterior end of the small extracted tooth, the right one, shows typical incisor structure, a large pulp canal with walls thin at the base and progressively increasing in thickness anteriorly. Both small incisors show indistinct longitudinal striations and the left one has a well marked groove on the anterior face of the lower half of the exposed portion. There is no indication of a bony septum in the alveolus separating the small from the large incisor. There is nothing about the supernumerary teeth to indicate that they would not have persisted until or throughout adult life.

Rudiments of incisors have been described in the house mouse by Woodward[4] and in the Sciuridae by Adloff,[5] both authors giving reviews of the subject and many bibliographic references. The position of these vestigial teeth, occurring only in early embryonic life, as illustrated by these authors is essentially the same as with the porcupine, that is anterior to the permanent tooth.

To account for these anomalous teeth in the porcupine three explanations may be considered. First, that the occurrence is simply pathologic without any other significance. Second, that the small incisor corresponds to one of the incisors lost from the normal mammalian dentition in the evolution of the rodents. In that case it ought to lie in a separate alveolus. Third, that it is a hypertrophied and persistent milk incisor, the view that I consider the most rational. The occurrence of persistent or least partially persistent milk incisors is not infrequent in man, the mammal in which abnormal conditions most frequently come to notice.

In conclusion, I wish to express my thanks to the authorities of the United States National Museum, particularly to Mr. Gerrit S. Miller, Jr., Curator, Division of Mammals, for the privilege of studying and recording this specimen.

[4] Anat. Anz., vol. 9, pp. 619–631, 1894.

[5] Zool. Anz., vol. 20, pp. 324–329, 1897; and Jena Zeitschr. Naturwiss., vol. 32, pp. 347–410, 1898.

THE CARRYING ANGLE

MORRIS KUSH

Ernst Philip Boas

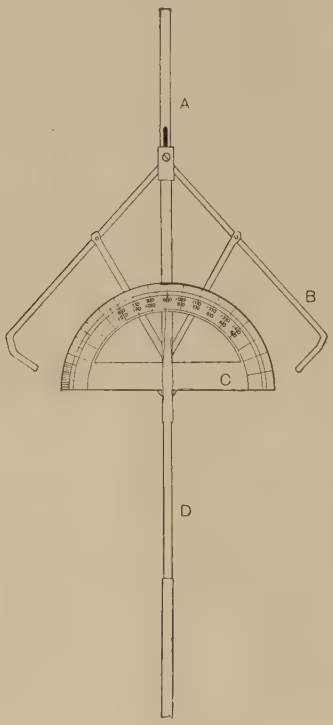
From the Mt. Sinai Hospital, New York City

ONE FIGURE

The late Dr. Morris Kush had begún a study of the carrying angle, which was cut short by his untimely death. It had appeared to him that the obliquity of the forearm in extension was greater in women than in men, in other words that the carrying angle was smaller in women; and he had planned to ascertain its size in adults and in children of both sexes, and to discover if possible the causes of the differences which he believed he would find. Among his papers were found some two hundred measurements of adult males and females. He did not have the opportunity to work these out thoroughly, but he was able to determine that the right carrying angle is smaller than the left one and that the angle in females is smaller than in males. From this point I have taken up the work along the lines which he had hoped to develop. I did not obtain measurements of children because I soon discovered that to endeavor to solve all of the questions suggested by an exhaustive study of the problem would be too formidable an undertaking at the present time.

The instrument with which Dr. Kush measured the carrying angle was of his own invention. It is depicted in the accompanying illustration. The instrument is placed on the anterior aspect of the extended and supinated arm with the bar (A), which is fixed to the protractor (C) at a right angle to its base, lying on the upper arm. The two side pieces (B) are then applied to the two epicondyles of the humerus. This brings the bar (A) into a line with the long axis of the humerus.

The lower bar (D) is then adjusted to the long axis of the forearm and the resulting angle is read off on the protractor. This angle, which is the one which appears in the tables, is the supplement of the carrying angle. The instrument admits of error because the upper bar is not applied to a fixed point on the upper arm. I have remeasured a number of the individuals whom



Dr. Kush had measured, and have found considerable variation between his figures and mine. But Dr. Kush had acquired a constant technique for himself, and so the relative values of the different measurements are significant, even if their absolute values may be questioned.

The bisacromial and intercristal diameters were measured with a pair of calipers.

In table 1 are recorded 105 measurements of adult males, and in table 2, 100 measurements of adult females. The indi-

viduals measured were patients at the Mount Sinai Hospital, New York City. The greater number of them are Russian Jews from the lower east side of New York City.

For purposes of ready comparison, all of the averages with their mean square errors are tabulated in table 3. The true carrying angles, i.e., the supplements of those in tables 1 and 2 are given.

A study of these figures justifies the conclusion that the carrying angle is smaller in females than in males. In 1895 Potter (1) made some measurements of the carrying angle, using "a narrow three foot rule, hinged at its center on the flat, having a disc, divided into degrees, attached firmly to one arm of the rule." The average size of the angle in 90 females was 167.35 degrees and in 95 males 173.17 degrees. He did not differentiate between the right and left arms. If in the present series we average the values of the right and left carrying angles we get 165 degrees for females and 167.7 degrees for males. The averages of the left carrying angles alone, in females is 166.6 degrees and in males 169.27 degrees.

A number of other observers report measurements of the carrying angle. Bertaux (2) figures are 168 degrees for females and 169 degrees for males. Braune and Kyrklund's (3) are 166.6 degrees for a series of eleven males. The average size of the carrying angle, without regard to sex, found by Malgaigne (4) was 165 degrees. Fère and Papin (5) record observations on a series of 194 cases. When we calculate the averages, we find the average for the right side to be 160 degrees, for the left side 161.2 degrees. Mall (6) reported measurements of the angle between the axis of flexion of the elbow joint and the long axes of the humerus and of the ulna respectively. The sum of these angles is the carrying angle, which may therefore be calculated from his tables. His averages for negro laborers are:

Males	right arm 170.0 degrees.	23 cases
Males	left arm 169.0 degrees.	26 cases
Females	right arm 166.5 degrees.	10 cases
Females	left arm 167.9 degrees.	11 cases

TABLE 1

Adult male—105 cases

AGE	RIGHT SUPPLEMENTARY CARRYING ANGLE	LEFT SUPPLEMENTARY CARRYING ANGLE	BISACROMIAL DIAMETER	INTERCRISTAL DIAMETER
	degrees	*degrees*	*inches*	*inches*
47	19	15	38	29
56	17	7	39	30
38	14	8	36	27
29	20	12	34	28
50	12	3	39	27
21	18	16	26	25
30	12	10	37	27
25	12	9	34	26
50	10	13	39	31
28	18	14	39	28
13	4	4	28	25
33	18	15	36	29
50	10	10	37	29
26	13	13	37	27
47	14	4	38	27
46	9	6	36	27
48	16	13	36	25
48	17	9	39	30
35	23	16	39	30
28	15	8	35	27
29	15	13	37	28
22	16	11	39	27
40	13	14	35	28
39	6	4	38	25
23	15	14	38	27
64	10	6	34	27
32	8	7	37	29
34	18	20	35	27
26	11	9	38	28
64	14	12	39	30
78	15	12	38	29
19	25	20	34	25
68	15	5	37	32
50	12	16	37	31
60	12	8	39	30
23	9	6	37	26
15	20	14	32	24
57	11	7	37	30
53	7	12	35	29
49	18	16	35	29

TABLE 1—Continued

AGE	RIGHT SUPPLEMENTARY CARRYING ANGLE	LEFT SUPPLEMENTARY CARRYING ANGLE	BISACROMIAL DIAMETER	INTERCRISTAL DIAMETER
	degrees	*degrees*	*inches*	*inches*
37	15	6	38	30
36	13	13	37	27
35	11	7	38	28
33	12	10	38	31
26	5	5	40	30
25	16	14	38	28
20	11	9	38	28
18	18	16	35	27
13	12	7	39	28
19	17	14	37	28
31	26	12	36	27
58	15	12	38	29
45	10	13	35	26
18	21	16	32	27
30	11	12	36	28
58	7	5	35	25
20	14	11	35	27
39	16	13	39	29
43	14	14	37	29
29	12	10	36	27
52	13	10	37	27
45	15	13	35	27
29	6	3	36	28
42	16	13	39	29
30	16	14	35	27
30	16	14	39	28
22	16	16	38	27
51	13	12	35	25
58	10	8	40	28
28	18	12	40	29
45	12	14	38	30
54	19	19	38	31
25	11	14	32	28
54	11	4	35	29
16	10	3	38	29
62	13	10	36	30
46	13	10	40	31
41	13	10	35	28
18	7	5	40	29
28	10	9	40	28
36	17	12	36	28

TABLE 1—Continued

AGE	RIGHT SUPPLEMENTARY CARRYING ANGLE	LEFT SUPPLEMENTARY CARRYING ANGLE	BISACROMIAL DIAMETER	INTERCRISTAL DIAMETER
	degrees	*degrees*	*inches*	*inches*
48	10	5	37	28
39	8	7	40	29
40	12	8	35	29
30	9	4	29	29
31	10	13	40	30
41	12	8	39	28
45	21	17	38	32
56	8	5	40	29
28	12	12	37	27
32	15	12	38	28
51	20	14	35	26
43	15	12	35	29
67	13	13	34	27
52	10	7	35	28
46	16	15	35	30
26	9	13	38	29
58	18	12	36	28
30	13	12	38	29
21	17	14	43	30
22	17	18	33	26
39	17	8	33	27
44	16	13	34	30
24	12	9	37	27
22	16	13	40	28
Average.....	13.66	10.83	36.5	28.07
Mean square deviation...	16.68	15.18	7.46	3.24
E	±4.08	±3.89	±2.73	±1.8

In whites the angle is about 169 degrees. The cases reported are too few to allow a comparison of males and females and of right and left. Nagel (7), using an instrument similar to Dr. Kush's, made an exhaustive study of the angle of the elbow. From a study of thirty males and thirty females he found that the carrying angle was 170 degrees in the former and 168 degrees in the latter. There was no difference between the right and left sides. Thus all of the authors agree that the carrying angle is smaller in females than in males, although

TABLE 2

Adult female—100 cases

AGE	RIGHT SUPPLEMENTARY CARRYING ANGLE	LEFT SUPPLEMENTARY CARRYING ANGLE	BISACROMIAL DIAMETER	INTERCRISTAL DIAMETER
	degrees	*degrees*	*inches*	*inches*
20	15	9	35	30
34	12	12	30	32
31	15	19	35	30
22	18	11	28	29
25	18	11	37	28
50	13	15	33	28
17	14	12	34	29
50	13	8	32	29
22	13	16	35	30
58	20	17	30	27
38	16	9	35	30
25	11	10	32	27
22	20	14	29	25
54	25	20	33	28
25	20	16	33	24
21	13	10	32	25
26	15	12	32	27
21	17	15	35	29
26	9	8	30	26
38	15	13	33	30
32	15	13	29	26
53	15	15	32	29
27	20	18	32	27
25	11	14	35	27
49	19	15	32	27
43	15	11	33	30
40	15	9	33	29
38	20	19	32	30
28	15	8	34	29
22	17	15	33	27
20	14	10	35	29
15	20	16	32	27
41	18	15	32	28
59	18	15	33	29
38	14	11	35	30
40	16	13	35	31
35	8	5	33	25
32	20	16	34	29
23	18	15	31	27
36	15	13	33	27

TABLE 2—Continued

AGE	RIGHT SUPPLEMENTARY CARRYING ANGLE	LEFT SUPPLEMENTARY CARRYING ANGLE	BISACROMIAL DIAMETER	INTERCRISTAL DIAMETER
	degrees	*degrees*	*inches*	*inches*
27	18	17	35	28
48	14	11	32	28
53	14	12	36	29
26	18	17	33	28
54	15	18	37	32
37	22	16	31	28
25	17	12	32	28
42	19	12	34	27
48	15	14	30	28
36	22	20	32	28
20	20	18	33	28
30	20	16	31	29
19	19	15	33	25
28	18	15	29	26
48	15	10	30	30
24	17	8	34	28
27	8	6	34	31
31	12	4	29	28
54	19	17	30	30
48	21	14	30	27
29	14	13	34	29
30	12	7	30	27
38	14	13	31	29
44	14	16	30	27
46	14	10	32	25
47	26	13	32	28
50	18	19	33	30
55	17	25	32	29
59	19	13	31	29
24	23	20	32	26
35	20	12	30	28
23	15	13	33	29
42	12	12	30	27
35	14	11	34	27
52	16	13	33	30
34	13	8	35	30
29	20	15	31	28
40	16	10	32	27
36	18	14	35	30
	19	13	32	26
22	10	7	31	26

TABLE 2—Continued

AGE	RIGHT SUPPLEMENTARY CARRYING ANGLE	LEFT SUPPLEMENTARY CARRYING ANGLE	BISACROMIAL DIAMETER	INTERCRISTAL DIAMETER
	degrees	*degrees*	*inches*	*inches*
25	24	23	33	29
26	20	18	33	26
28	15	16	34	30
29	18	16	32	26
28	18	15	33	27
39	20	18	33	31
24	13	11	33	30
41	15	8	32	29
28	16	11	30	25
32	19	18	32	29
42	16	11	30	26
14	19	18	30	26
42	12	12	34	30
25	16	14	35	31
55	16	15	36	33
48	16	12	30	26
32	20	11	32	27
17	20	14	34	27
33	12	9	31	28
Average.....	16.47	13.42	32.46	28.15
Mean square deviation...	12.12	14.11	3.63	3.13
E.....	±3.48	±3.76	±1.9	±1.75

TABLE 3

SEX	RIGHT CARRYING ANGLE	LEFT CARRYING ANGLE	BISACROMIAL DIAMETER	INTERCRISTAL DIAMETER
	degrees	*degrees*	*inches*	*inches*
Male.....	166.3±0.39	169.2±0.38	36.5±0.27	28.1±0.17
Female.....	163.5±0.35	166.6±0.38	32.5±0.19	28.1±0.17

there is disagreement as to the degree of difference, and as to the absolute size of the carrying angle.

It was at first thought that this difference might be due to the relatively greater intercristal diameter in women which might cause a compensatory increase of the obliquity of the forearm in extension, in other words a decrease in the carrying angle. The coefficient of correlation between the right carrying angle

and the intercristal diameter was therefore calculated. It is −0.01 in males and −0.131 in females, too small to have any significance. The coefficient of correlation between the right carrying angle and the bisacromial diameter is also very small −0.054 in males and −0.091 in females. The figures show that there is no correlation between the carrying angle and the difference between the bisacromial and intercristal diameters. The smaller carrying angle in women, therefore, is not due to their narrower shoulders and relatively broader pelvis.

No anatomical feature appears to account for the difference in size of the carrying angle in the two sexes. The cause of this difference, whatever it may be, acts equally on the right and the left arms, for the coefficient of correlation between the right and left angles is high, +0.639 in males, and +0.67 in females. A glance at the averages in table 3 suggests that the dissimilarity between the two sexes may have a physiological, rather than an anatomical basis. In males as well as in females the right carrying angle is distinctly smaller than the left one. This is probably due to physiological factors.

The likelihood of this interpretation is enhanced by measurements of the carrying angle in left handed individuals. In table 4 are recorded the carrying angles of twelve left handed persons.

In this series the right carrying angle is on the average only 0.33 degree smaller than the left one, while in right handed individuals it is about 3 degrees smaller. Left handed persons are usually, to a certain degree, ambidextrous, while right handed persons favor the right hand more exclusively; therefore, if the size of the angle depends on physiological moments, the difference between the two sides will not be so marked in left handed individuals. Moreover, among these few observations there are two which are widely divergent from the others, 154 degrees, right and 167 degrees left, and 163 degrees right and 173 degrees left. These may be incorrect, especially since Dr. Kush had placed a question mark next to the first of these observations. If that were so, the average left angle would be smaller than the average right one.

TABLE 4

Left handed individuals

SEX	RIGHT CARRYING ANGLE	LEFT CARRYING ANGLE
	degrees	*degrees*
Female	167	164
	169	166
	154	167
	165	164
	170	167
	163	173
	162	160
Male	167	166
	170	167
	168	166
	171	167
	168	171
Sum	1994	1998

Thus we find the carrying angle smallest in the arm which is most used. By analogy it is possible that the difference in the angle in the two sexes is dependent on physiological factors. It would be interesting to compare the carrying angles of series of individuals having widely different occupations, e.g., railway porters and clerks.

On the basis of different observations, Nagel arrived at the same conclusion. From a study of the relationship of the carrying angle to the angle between the axis of flexion of the elbow and of the long axes of the humerus and ulna respectively, to the olecranon angle, to the angle of torsion of the humerus, and to various other anatomical landmarks, he became convinced that the size of the carrying angle was determined by no anatomical factor. He found that in many individual cases intensive use of the arm, as shown by a strongly developed musculature, caused greater obliquity of the forearm. For instance, in athletes the carrying angle was 6 degrees smaller than in selected weak armed individuals. Vice versa children showed only a slight obliquity of the forearm. Braune and Kyrklund made the same observation in children. Although Nagel's averages showed no difference in size between the right and left angles,

persons who were markedly left handed were found to have smaller left than right carrying angles. In one case the difference was 8 degrees. From all of these facts, Nagel concluded that the size of the carrying angle was determined by physiological factors.

Although irrelevant to the body of this paper, it may be mentioned that the coefficient of correlation between the intercristal and bisacromial diameters is +0.389 in males and +0.45 in females. There is therefore a definite relation between the two.

SUMMARY

The carrying angle in females is about 3 degrees smaller than in males.

The right carrying angle in males as well as in females is about 3 degrees smaller than the left one.

In left handed individuals the right and left carrying angles are about equal. (This conclusion should be verified by a larger number of cases.)

There is no relation between the carrying angle and the bisacromial or intercristal diameters.

The difference in the size of the carrying angle in the two sexes, and in the right and left sides is not dependent on anatomical, but on physiological factors.

There is a close correlation between the right and left carrying angles, and also between the intercristal and bisacromial diameters.

LITERATURE

(1) Potter, H. P. 1895 The obliquity of the arm of the female in extension. The relation of the forearm with the upper arm in flexion. Jour. Anat. and Physiol., 29.

(2) Bertaux 1891 L'humerus et le Femur, etc. Thèse pour le Doct. en Med. Lille. Quoted from Nagel, l.c.

(3) Braune, W. and Kyrklund, K. 1879 Archiv f. Anatomie u. Physiologie, Anat. Abt. p. 321.

(4) Malgaigne, J. F. Traité d'anatomie Chirurgicale et de Chirurgie expérimentale, 2d ed. 2, 634.

(5) Fère, C. et Papin, E. 1902 Notes sur quelques varietés de la direction du membre superieux. Jour. de l'Anat. et de la Physiol., 38, 105.

(6) Mall, F. P. 1905 On the angle of the elbow. Am. Jour. Anat., 4, 391.

(7) Nagel, K. 1907 Untersuchungen ueber den Armwinkel des Menschen. Zeitschrift f. Morphologie u. Anthropologie, 10, 317.